



Mississippi State UNIVERSITY

Center for Air Sea Technology

FY98 RESEARCH PROGRAM

by
Lanny A. Yeske and James H. Corbin

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Mississippi State University Center for Air Sea Technology
Stennis Space Center, MS 39529-6000

TECHNICAL REPORT 9-98

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CENTER FOR AIR SEA TECHNOLOGY
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by

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30 September 1998

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ABSTRACT

In FY98, the Mississippi State University (MSU) Center for Air Sea Technology (CAST) conducted research under several grants and contracts from a variety of governmental sources. This document reports on MSU CAST performance in these areas of:

- Modeling the Santa Barbara Channel Using Realistic Open Boundary Conditions and Winds under Office of Naval Research (ONR) Grant N00014-97-1-0525;
- Modeling with Data Assimilation in the North Atlantic (DAMEE) under ONR Grant N00014-97-1-0099;
- Applications of Numerical Models in the Coastal, Semi-Enclosed, and Marginal Seas Using the Relocatable Modeling Environment under ONR Grant N00014-95-1-0203;
- Development of a Master Environmental Library Client/Server and Advanced Development under NRL Contracts N00014-95-C-6032 and N00173-98-C-6012;
- Development and Maintenance of the Naval Interactive Data Analysis System (NIDAS) for NAVOCEANO and Commander Mine Warfare Command under NASA Contract NAS13-564 Delivery Orders 131 and 132;
- Software Infrastructure Support for Environmental Protection Agency/ Gulf of Mexico Program Office under Contract MXS984100-97-0;

Finally, this report summarizes CAST FY98 publications, presentations and demonstrations, offices held, sponsored seminars, professional recognition, interdisciplinary activities, meetings attended, submitted proposals, and contracts awarded.

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1.0 INTRODUCTION

The Mississippi State University (MSU) Center for Air Sea Technology (CAST) evolved from the Institute for Naval Oceanography's (INO) Experimental Center for Mesoscale Ocean Prediction (ECMOP) which was started in 1989. MSU CAST subsequently began operation on 1 October 1992 under a single ONR research grant. In FY98, MSU CAST continued to operate under three separate grants with ONR. In addition, MSU CAST was successful in obtaining several other research contracts from NAVOCEANO, NRL, and EPA.

In the past, MSU CAST technical research and development has produced tools, systems, techniques, and procedures that improve efficiency and overcome deficiency for both the operational and research communities residing with the DOD, private industry, and the university ocean modeling community. We continued this effort with the following thrust areas:

- Develop advanced methodologies and tools for model evaluation, validation and visualization, both oceanographic and atmospheric;
- Develop a system-level capability for conducting temporally and spatially scaled ocean simulations driven by or are responsive to ocean models, and incorporates the coupling to atmospheric models;
- Develop an oceanographic/atmospheric data management system with emphasis on distributed databases in a network environment, with database optimization and standardization, including use of World Wide Web (WWW);
- Implement a high performance parallel computing technology for CAST ocean models; and
- Implement new software applications and systems into a distributed object computing environment utilizing government and industrial standards such as CORBA (Common Object Request Broker Architecture), and the Extensible Distributed Graphical Environment (EDGE).

The CAST approach employs the most recent technological advances in database management, graphics/visualization, and network communications including the WWW. CAST deliverables include:

- Implementation of a laboratory-like capability for oceanographic and atmospheric model evaluation and validation that incorporates measurements of performance skill;
- Development of high resolution coastal models based on DieCAST;
- An economical data access solution and distributed database capability for networked database users, including DOD components;
- New model visualization and animation tools for analyzing and assessing model output; and
- Implementation of network file browsing capability and use of the WWW for general database access and educational applications.

This technical document reports on the results of the research conducted in FY98. In particular, in Section 2.0 we discuss the research conducted with ONR, Section 3.0 with NRL, Section 4.0 with NAVOCEANO, and Section 5.0 with EPA. Section 6.0 provides information on CAST current facilities and personnel. This is followed by an Appendix which summarizes for FY98 CAST publications; presentations and demonstrations; offices held; sponsored seminars; sponsored workshops and meetings; professional recognition and awards; interdisciplinary activities; workshops and meetings attended; and submitted proposals/contracts awarded.

2.0 RESEARCH PROJECTS WITH ONR

For FY98 ONR funded the following projects:

- Modeling the Santa Barbara Channel Using Realistic Open Boundary Conditions and Winds (\$100K)
- Modeling with Data Assimilation in the North Atlantic (DAMEE) (\$100K)
- Applications of Numerical Models in the Coastal, Semi-Enclosed, and Marginal Seas Using the Relocatable Modeling Environment (\$100K)

2.1 Modeling the Santa Barbara Channel Using Realistic Open Boundary Conditions and Winds

A modified Arakawa "a" grid SBC version of DieCAST was nested within the CC model developed in collaboration with NPS (Drs. Bob Haney and Bob

Hale). Even with no sponge layers, the open SBC boundaries had little noise. The nested SBC results (1/60 degree resolution) were consistent with the lower resolution (1/12 degree) CC model results in the same region, yet rich in internal smaller-scale features that were not resolved by the coarser CC model.

Observed coastal mesoscale (40 km wide, 3-10 dynes/cm-cm) wind forcing jets were added to the CC model. These elongated jets stretched southward from main coastal headlands. Their monthly mean surface stress was ~ 3 dynes/cm-cm along the jet centerline. Synoptic events often give $O(10)$ dynes/cm-cm.

Results using Hellerman summer winds, enhanced by the 3 dyne/cm-cm summer mean forcing, showed significant differences compared to results using only Hellerman winds. Thus, it may be necessary for coastal models to respond accurately to such small (40 km) scale wind jets to get realistic near-shore flow results. DieCAST responded strongly using 1/12 deg resolution.

The SBC had near zero mean through flow, because of a near balance between a local-wind-forced surface Ekman layer flow and its associated upwelling (northern SBC) and downwelling (southern SBC) distribution, and external effects from the Davidson Current and the CC system. Fluctuations away from this near balance led to the four main SBC regimes.

Based on a series of sensitivity studies with our 1/60 deg resolution SBC model nested in our 1/12 deg resolution CC model, culminated by those reported by Dietrich and Mehra (1998), we have achieved a good understanding of the SBC general circulation dynamics: the SBC general circulation is primarily an Ekman layer response to local wind forcing modified by stratification, dissipation and mixing along its perimeter, and open boundary effects from the CC.

We also have demonstrated (Dietrich and Mehra, 1998) that our SBC model nested in our CC model gives realistic mean flow as well as the main observed flow regimes reported by Harms (1996). This includes details such as a stronger eastern port time mean inflow at 50 m depth than at the surface. The main findings from this research, supported by results shown by Dietrich and Mehra (1998), include:

- Given realistic climatological wind forcing with the annual cycle specified only in the mountain shadow winds (no mountain shadow during winter), the DieCAST model gives surface and 50 m depth mean flows (Dietrich and Mehra, 1998) that are strikingly similar to observations reported by Harms (1996).

- Local wind forcing is a critical issue. A very narrow (~8 km) mountain shadow along the north rim of the SBC, together with wind turning into the channel along the south rim, as observed, is required to get realistic mean climatological westward north rim and eastward south rim flows in the SBC central basin, and the main observed fluctuations from the mean.
- The local wind forcing effects are primarily through its associated surface Ekman layer drift and upwelling distribution, rather than direct vorticity generation by wind curl.
- The upwelled CC coastal jet water tends to separate near Point Conception, and entrain some of the flow from the east along the north rim of the SBC (the rest recirculates within the SBC). It thus has substantial effects on the SBC circulation, as we correctly hypothesized earlier.
- The mean latitudinally averaged flow through the SBC is small, but oscillates. This, together with peripheral small-scale mixing eddies around the SBC rim, suggests that dissipation may play a major role in the maintenance of the dominant central cyclonic vortex, based on simple absolute potential vorticity dynamics mechanisms. This is discussed by Dietrich and Mehra (1998). Similar mechanisms were previously discussed by Bretherton and Haidvogel (1976); Salmon, Holloway and Hendershott (1976); and Carnevale and Frederiksen (1987). This mechanism tends to maintain cyclonic flows over deep central basins of semi-enclosed seas, including the Adriatic Sea and Black Sea, as well as the SBC.

We thus expect that, given accurate synoptic winds and open boundary conditions, the DieCAST model will give accurate nowcast/forecast results. Hindcast synoptic wind inputs are presently being prepared by our collaborators at NPS, in order to have a consistent basis for comparison of the DieCAST and Princeton Ocean Models. Such comparison will lead to better understanding about coastal modeling capabilities in general (DieCAST and Princeton are quite different, so good information should result) as well as the relative strengths and weaknesses of the individual models.

In summary, surface Ekman layer flows and associated upwelling suggest that it may be necessary to accurately specify local wind forcing as well as the Davidson Current and other external effects in order to forecast the SBC beyond a few days. Direct local vorticity generation by local wind curl may be secondary. Our SBC-demonstrated nesting technology has potential for detailed coastal nowcast/forecast systems.

An impact of this research is that we now have a working one minute (approximately two kilometer) horizontal resolution, 20-vertical level, SBC Model that shows extremely detailed flow features and local wind sensitivity. In conjunction with researchers at NPS, we also have a five minute resolution CC model with which we are implementing two-way nesting with our SBC model.

The SBC model runs about one model week per cpu-hour on a Silicon Graphics Indigo 2 workstation. On a newer Pentium Pro PC, the SBC model will run more than one month per cpu day. The DieCAST model has thus been shown to have potential for high resolution shipboard coastal forecast applications.

REFERENCES:

Dietrich, D. E. and A. Mehra (1998). External and Local Wind Forcing of Santa Barbara Channel Circulation. Quality Review Board (ORB) Minutes of Meeting No. 6, 4-6 February 1998, 229-253.

Harms, S. (1996). Circulation Induced by Winds and Pressure Gradients in the Santa Barbara Channel, Ph. D. Thesis, Univ. of California at San Diego, Scripps Institution of Oceanography.

Bretherton, F. P. and D. B. Haidvogel (1976). Two-Dimensional Turbulence Over Topography. J. Fluid Mech., 78, 129-154.

Salmon R., G. Holloway and M. C. Hendershott (1976). The Equilibrium Statistical Mechanics of Simple Quasi-Geostrophic Models. J. Fluid Mech., 75, 691-703.

G. F. Carnevale and J. S. Frederiksen (1987). Nonlinear Stability and Statistical Mechanics of Flow Over Topography. J. Fluid Mech., 175, 157-181.

2.2 Modeling with Data Assimilation in the North Atlantic (DAMEE)

For the past few years, DAMEE-NAB has addressed the climatological behavior of different prognostic circulation models as per a fixed list of well documented properties of the NAB. Some forecast experiments on the target domain of the North Atlantic Subtropical Gyre have also been performed. These experiments entailed various data assimilation methods and emphasized synoptic time-scale predictions. All such experiments have been performed at a low resolution of 1/2 degree with fewer than 20 vertical levels. Future participants of DAMEE-NAB are addressing the sensitivity of mesoscale forecasts to variations in climatological measures and are also establishing basin-scale predictive capabilities of general circulation models relative to persistence and climatology

at higher resolutions ($\sim 1/10$ degree) horizontally and a larger number of vertical levels (up to 40). Some other goals include identifying the strengths and weaknesses of different classes of numerical models and various data assimilation techniques. Exploring and implementing the best data assimilation methods with coupled models will be the final step for accurate, efficient forecasts of the North Atlantic Basin.

The DieCAST model has emerged as being very accurate and robust in applications to near-coast features such as boundary currents and shelf break currents, and their interactions with deep water eddies. Modeling of such features requires accurate simulation of the baroclinic pressure gradient which DieCAST performs successfully, as found during extensive studies of the Gulf of Mexico (GOM). DieCAST has been deployed and validated in different regions of world oceans. Most prominent studies have been in the California Current, Arctic Ocean, and Tasmanian Sea. Studies involving a one degree global version of the model are also in preliminary stages with promising results.

Recently DieCAST, with a modified Arakawa "a" grid scheme, was successfully implemented in the NAB at $1/2$ degree resolution and with ten vertical levels. The domain extended from 15° S to 65° N. It included the entire NAB and Atlantic Equatorial Region, but excluded the GOM. The vertical viscosity was determined by a method based on the Richardson number, while realistically low horizontal diffusivities were specified to model the circulation. Results indicate active inertial eddy fields caused by the implementation of higher-order interpolations and by modifying the incompressibility algorithm to substantially reduce dispersion. Even at a coarse resolution of $1/2$ degree, the Gulf-Stream separation seems robust and other well-known features of the North Atlantic Sub-tropical Gyre were reasonably simulated.

The FY98 CAST research effort focused on the following five tasks:

- Task 1: DieCAST Implementation on the Standard Domain for DAMEE-NAB Model Comparison Experiment. To accomplish inter-model comparison, a modified Arakawa "a" grid version of DieCAST was run on the standard domain stretching from 6° N to 50° N and from 98° W to 6° W with three degree buffer zones at the northern, southern, and eastern boundaries. Ten year simulations were carried out with data saved from the last three years of the integration for analysis. Properties evaluated for performance assessment included vertical cross-sections of T and S, Florida Strait transport, SST and SSH means, mean and eddy kinetic energy distributions, etc. These results were compared and evaluated against available observations, Levitus 1994

Climatology, and other models. These comparisons will appear in a future special issue of Deep Sea Research on the DAMEE-NAB.

- Task 2: DieCAST Implementation at High Resolution (1/3rd Degree) on an Extended North Atlantic Domain. A high resolution version of DieCAST was implemented on an extended NAB domain from 15° S to 75° N and from 98° W to 15° E. The larger domain was desirable to provide more realistic water mass transformation time scales and associated dynamic effects on the NAB thermohaline circulation. Results showed many realistic detailed features including sustained Gulf Stream (GS) separation near Cape Hatteras; an active transient eddy field north of the GS with many pinched off warm core eddies; all three branches of the Labrador Current; a prominent persistent anticyclonic Taylor column over the Flemish Cap; a small semi-permanent cyclone pair in the southeastern Flemish Cap region; narrow GS water mass elements that enter a loop current between the cyclonic pair with the loop regularly pinching off eddies into the Labrador Sea, thus ventilating the North Atlantic Gyre in a similar way that eddies ventilate the Gulf of Mexico; North Brazil Current with retroflexion eddies; and a cyclonic western Mediterranean Sea gyre. A detailed description of these results has been submitted as a manuscript to Deep Sea Research.
- Task 3: Parameter Sensitivity Studies in NAB. Parameter sensitivity studies were also conducted in the NAB using DieCAST. These included the influence of vertical resolution on the thermocline and other flow features, effect of drag coefficient on Florida Strait transport, and comparison of results with different wind stress climatologies. A new surface restoring condition, derived from an atmospheric energy balance model, was also implemented.
- Task 4: Thermohaline Circulation Studies of NAB. The vigorous water mass transformation in the Labrador and GIN Seas strongly affects the thermohaline circulation of the entire NAB. This water mass transformation is addressed by: (a) maintaining a diagnostic time mean of model surface heat and salinity fluxes at all horizontal grid points; (b) adding the long term mean model heat and salinity heat fluxes to the surface layer each time step; (c) after adding the long term mean fluxes, restoring to Levitus 1994 Climatology with 0(180) day restoring time scale at each time step; and (d) using the streamfunction for the zonally averaged flow to diagnose thermohaline effects on the meridional circulation. To parameterize Arctic Basin water mass transformation, a buffer zone along the northern boundary of the modeled region was used in the 1/3 degree model. A northern GS water branch jets to the

NE corner of the modeled region, but turned sharply westward in the buffer zone where its water mass was quickly restored toward climatology. An alternative to this short-circuited Arctic water mass transformation was to open the NE corner for outflow and specify an East Greenland Current inflow (return flow from Arctic basin). In the reduced DAMEE-NAB standard domain, Arctic Basin, GIN Sea and Labrador Sea water mass transformations were parameterized by a similar buffer zone near 50°N.

- Task 5: Data Assimilation Development. The main focus of the data assimilation development effort was to ingest the satellite data on SSH observed regularly. The main concern was to develop an objective methodology to project the surface information to subsurface levels, so that the overall numerical state of the system stayed in an approximate dynamical balance. Any small anomalies from the balance were expected to dissipate in a few further few steps of model integration.

The approach was to use optimum interpolation (OI) of the observed satellite SSH, followed by geostrophic adjustment of the subsurface current velocities due to changes induced by the differences in the observed SSH from the model SSH. This adjustment was facilitated by the use of correlation factors obtained between SSH and sub-surface hydrography at model grid points.

To complete this task, details of the OI method are presently being investigated by application to the standard DAMEE-NAB domain using Topex/Poseidon data for Calendar Year 1993. Results with and without data assimilation will be evaluated at suitable model grid points against available XBT/CTD data for the same year.

This research demonstrated that DieCAST realistically simulates detailed coastal and deep water features using lower resolution and significantly less computing than required by other ocean models. This was due to using fully fourth-order accurate numerical schemes, which had very low numerical dispersion, and were uniquely robust with realistic unfiltered topography and realistically small viscosities. Accordingly, we delivered diagnostics for inter-model comparisons, with results submitted to refereed journals for publication.

2.3 Applications of Numerical Models in the Coastal, Semi-Enclosed, and Marginal Seas Using the Relocatable Modeling Environment

A majority of the world's population lives within 100 miles of the world's coastlines and is therefore heavily dependent on the coastal and marginal seas for transportation, food, recreation, etc. The coastal and marginal seas have also become more central to U.S. national security. Therefore, a better understanding of the circulation in coastal and marginal seas is assuming increasing importance, and remotely sensed satellite data and numerical modeling play an important role.

The many steps and logistics of setting up a relocatable numerical model in a new region of interest are quite tedious and labor intensive. Much of this effort can be simplified with modern computer technology. For example, in setting up the 2D Colorado University Rapidly Relocatable Nested Tide and Storm Surge (CURReNTSS) Model one needs to: specify the domain, define the model grid and resolution, select the appropriate bathymetry database and extract the data, edit the bathymetry for errors such as opening closed channels, select and extract ancillary data such as the IHO tidal station data, make sure that the stations fall on a grid over water instead of land, edit the ancillary data to correct errors, define the model boundaries, specify the model boundary conditions, generate the model header files, and generate the model input and initialization files. Each of these steps need to be completed before the model can be run to obtain the first output. This process can consume anywhere from a couple of days to weeks depending on the complexity of the domain and data. For more complex 3D data assimilating circulation models there are even more steps involved. After the model run, the user is still faced with postprocessing the model output and managing them systematically. But if the above steps can be accomplished quickly, the time saved can be invested in understanding the oceanographic effects and in responding to Navy needs quicker. In this complementary effort with Colorado University (CU), we are developing and testing appropriate tools under a RME with a user-friendly GUI that will enable modelers to rapidly relocate ocean models in any region of the world, and then to transition the integrated system to the Navy's research and operational communities.

The FY98 tasks and accomplishments were:

Task 1: Complete the Validation of the 2D CURReNTSS Model with Currents. The fully integrated 2D model had already been validated against tidal station data and sea level observations, and only the barotropic currents needed to be validated. To verify the model's ability to accurately predict barotropic tidal currents in two varied and complex regions of interest, validation exercises were performed with available observational data in the Yellow Sea and the North Atlantic Bight.

For the Yellow Sea, the barotropic influences weigh heavily in the coastal and shallow waters. An enhanced version of the CURReNTSS model, which was now capable of assimilating altimetric tidal gage data (from TOPEX) for improved predictions of tidal elevations and currents, was implemented in the Yellow Sea at a resolution of $1/5$ degree. The gridded domain extended from 117 to 131°E and from 24 to 41°N . The grid resolution resulted in a 71 by 86 grid. The bathymetry was interpolated from a $1/6$ degree Korean topographical database and other high resolution accurate databases provided by NAVOCEANO. The GUI provided data from 31 tidal stations which were assimilated into the model with a fixed weight parameter (0.9). Global results available via the GUI were used to set up the boundary conditions for the open boundaries (south and east) and eight primary linear tidal constituents were included, namely M_2 , S_2 , N_2 , K_2 , K_1 , O_1 , P_1 and Q_1 . The model was run for 20 days and forcing was provided from astronomical tides alone. A time series of induced tidal currents was obtained from the model output and compared against observed tidal currents at the nearest available location. The model results compared favorably with the observed values. The predicted tidal current phases matched well though some discrepancies were found in the magnitudes. These can be attributed to the fact that the model value represents the average value of the current over the grid-cell and not at a fixed point in space. Also, the model predicts depth-averaged currents unlike the observations which were obtained at a fixed depth of approximately 70% of the total depth.

The North Atlantic Bight boasts of some of the highest tidal ranges and fastest tidal currents in the world. CURReNTSS was run in a nested fashion at two resolutions. The larger coarser domain at $1/12$ degree covered the entire Bight from 77 to 63°W and from 35 to 45°N . The nested high resolution fine grid at one minute resolution, which mainly covered the Bay of Fundy and some parts of Gulf of Maine, extended from 68 to 64°W and from 44.5 to 45.5°N . The coarse resolution model was run first for ten days with astronomical forcing alone. An accurate bathymetry was generated by fusing ETOPO5, half minute NOS data, and an accurate (half minute) USGS topographic database. The boundary conditions were provided from the GUI as before, and tidal station data from 144 gages in the region were assimilated into the model. The model results were saved at the boundary of the nested fine grid. Next, the fine grid model was run with boundary conditions provided from the encompassing coarse model for ten days under similar forcing. The predicted tidal currents at points fixed a priori were used to calculate tidal ellipses which were compared against published Moody charts data for the Bight. The magnitudes of tidal ellipses (major and minor axes) matched well as did the tidal current phases and tidal ellipse orientations.

Task 2: Integration of the 3D Baroclinic Model. The 3D baroclinic model developed at CU under other ONR funding is a sigma-coordinate based, comprehensive physics 3D tidal model with data assimilation. It has been successfully used by NRL (in the Yellow Sea) and by NAVOCEANO (in the Persian Gulf) to provide estimates of tidal current structure in coastal, marginal, and semi-enclosed seas.

The RME GUI developed initially to support the 2D barotropic tidal model (CURReNTSS) was enhanced to support the 3D baroclinic model. Additional functionalities were built to address 3D sigma co-ordinate grid generation and 3D pre-processing. The GUI was modified to interpolate a given bathymetry (default DBDB5) to a user defined 3D grid and also to interpolate Levitus '94 (annual or seasonal) data to the model grid for initialization. Enhancements were also made to reduce the time-taken for the extraction of climatological fields from the Levitus database for a particular region.

The 3D GUI allows a user to visualize and edit horizontal sections of the grid at various sigma (or z) levels and vertical sections at user specified latitudes and longitudes. Similarly, hydrographic fields (temperature and salinity) can be visualized along horizontal and vertical sections.

To complete this task, the post-processing modules were enhanced to provide a time series of velocity components and elevations at any specified level at pre-defined grid points, and animate snapshots of results at any sigma (or z) level or any specified vertical section. The existing post-processing modules in the GUI already provided for tidal event logs and performed co-tidal and co-phase analyses.

Task 3: Validation and Comparison of ADCIRC Model. NAVOCEANO's ADCIRC Finite Element Model output was to be integrated into the RME for the purposes of model evaluation and comparison against available observational data. This was to be performed in close collaboration with NAVOCEANO. Because of a change of priorities at NAVOCEANO which resulted in a decision to stop further development of ADCIRC in new regions, in favor of using CURReNTSS to meet NAVOCEANO operational needs for tidal predictions, there was no longer any Navy interest in completing this task. Accordingly, no work was expended in this effort by CAST. At present, ADCIRC complements the CURReNTSS model.

3.0 RESEARCH PROJECTS WITH NRL

3.1 Master Environmental Library Client/Server and Advanced Development (\$638.5K)

The Defense Modeling and Simulation Office (DMSO) initiated and funded the Master Environmental Library (MEL) project to catalog and distribute key environmental datasets via the INTERNET using current and emerging technologies to support the modeling and simulation of tactical environmental scenarios. This project involves various DOD agencies from the Army, Navy, and Air Force, and academia. NRL has been designated by DOD as the lead agency for the MEL Task 2 development, and CAST is a subcontractor to NRL for development of the MEL Resource Site Software (MRSS).

The datasets currently available via MEL include environmental parameters from observations, operational numerical models, climatological databases, and others located at various sites across the country. At the core of MEL is a "Library Structure" (MEL/LS) that incorporates the environmental databases distributed across remote sites, a distributed catalog system with centralized access for "One Stop Shopping" of environmental data required by the modeling and simulation (M&S) community, and clients to browse and access data/meta-data. The World Wide Web (WWW) over the INTERNET has been identified as the vehicle of choice to implement MEL. The location of the databases and components of the sub-system are transparent to the users. The users can exercise the system remotely using a WWW client such as Netscape from a variety of hardware platforms including Unix machines, desktop PCs, and Macintosh computers. From this environment the users can perform queries based on their region and time window of interest for their choice of environmental parameters. No apriori knowledge of the location of the databases and their formats is necessary. Once the user identifies a dataset of interest, he/she can submit a request for retrieval which is processed asynchronously. The extracted dataset can be transferred to the user via ftp, email, or U.S. mail on tapes or disks. Also, a subscription mechanism has been implemented to allow the users to subscribe to data products that are routinely generated.

CAST, early in FY95, received modest funding from NRL to begin preliminary work on the MEL. A subsequent three-year contract was given to CAST under NRL Broad Agency Announcement 95-1 and Contract Number N00014-95-C-6032 and the following tasks were accomplished: design, implement, and document the MRSS which was initially known as the MEL/LS Regional Request Handler; the purchase and installation of dedicated MEL hardware for several resource and developmental sites; the provision of support to various sites and other DMSO sponsored activities such as the Surfzone Project

and other training/exercises via MEL; and the survey of other potential MEL users and assisting them in defining their data needs with respect to MEL.

More specifically, MEL resource sites now online include:

-NRL	Monterey, CA
-MSU CAST	Stennis Space Center, MS
-Air Force Weather Agency	Omaha, NE
-Air Force Combat Climatology Center	Asheville, NC
-National Geophysical Data Center	Boulder, CO
-Army Research Laboratory	White Sands Missile Range, NM
-National Imagery and Mapping Agency	Fairfax, VA (Unclassified Site)
-National Imagery and Mapping Agency	St. Louis, MO (Classified Site)
-Air Force Simulator Database Facility	Kirkland Air Force Base, WA

The MSU CAST site supports the DMSO sponsored Surfzone Project at NRL Stennis Space Center and elsewhere. In addition, the Naval Oceanographic Office participated in testing a prototype version of the MEL Access Site Software to determine special implementation considerations needed at an "operational" vice "research" site.

The following sites have been approved to be part of MEL in the future:

-Naval Oceanographic Office	Stennis Space Center, MS
-Army Topographic Engineering Center	Alexandria, VA

In addition, the following activities have been approved as "candidate sites":

-Air Force Research Laboratory	Hanscom Air Force Base, MA
-Army Research Laboratory-Battlefield Environment Directorate	Adelphi, MD
-Seventh Army Training Command Terrain Simulator Center	Grafenwoehr, Germany

The MEL Resource Site Software (MRSS) Version 1.1 has been released to all sites, as has the MRSS Administrator's Guide (also known as the MEL Software Center Operator's Manual).

A follow-on contract (N00173-98-C-6012) for Advanced Development of MEL was given to CAST that extends and expands our existing research program through FY00. This effort also involves collaboration with Physitron, Inc. Physitron and CAST have a four-year history of research collaboration based on

the CORBA standard and the Distributed Object Computing (DOC) paradigm. The primary area of proposed research is structured to experiment with DOC methodologies and CORBA standards whereby environmental data of all types can be indexed, archived and rapidly disseminated within a distributed computing network environment. The research will be conducted in a network laboratory setting composed of widely separated data resource nodes located at the major DoD and other Federal centers. CAST will perform comparative studies, design and carry out simulation experiments, and demonstrate advanced capabilities for optimizing the acquisition, storage and distribution of gigabyte/terabyte-size volumes of atmospheric, oceanographic, terrain and near-space environmental information. The major research issues to be addressed are:

- A Restructuring of Research Roles. The primary effort of CAST has focused on data resource node capabilities, while NRL has focused on the functionality of a central controlling node. Based on experience, CAST, in collaboration with Physitron, will expand its effort by incorporating the central node studies and restructuring the effort to focus on more fundamental research topics.
- The Data Problem. Without reliable access to validated data, no model or simulation is capable of demonstrating its intended purpose. The DMSO vision for applying environmental information in defense models and simulations recognizes this dependency on data, specifically rapid and reliable access to data archival and collection centers. This vision also maps well to the technological progress that will enable rapid dissemination of future environmental data to DoD operational forces. To fulfill this vision, CAST believes an integrated research effort is necessary - one that examines all aspects of "the data problem". While progress has been made during the past several years, advancing communications and computational technologies serve only to quicken the pace at which new concepts must be studied and analyzed. CAST will conduct research in three specific thrust areas that address the environmental data requirements of the M&S research community: (1) Advanced Distributed Software Concepts, (2) Experiments in Optimal Environmental Data Access, and (3) Collaborative Research Efforts.

4.0 RESEARCH PROJECTS WITH NAVAL OCEANOGRAPHIC OFFICE

4.1 Naval Interactive Data Analysis System (NIDAS) Development and Maintenance (\$116K)

The objective of NIDAS is to provide NAVOCEANO with an interactive overlay capability for several types of oceanographic, meteorological, and satellite derived data; create 3-D gridded fields of temperature and salinity profiles constructed from a combination of "provinced" data (user derived) and gridded data; and provide a user's manual and training of NAVOCEANO personnel in the new software system.

Phase I tasks completed in 1994 were to ingest static databases into a CAST installed EMPRESS/NEONS system; prepare final design/database specification documents; ingest revolving databases into EMPRESS/NEONS; design and develop additional application programs to provide the capability to interactively view and evaluate the OTIS fields by comparison with other fields; assist NAVOCEANO in interfacing the system to the classified POPS via the LAN to ensure the continuity of NIDAS operational commitments; train NAVOCEANO personnel in system operation; and provide informal monthly demonstrations. Phase II tasks completed in 1995 were to make the system relocatable on short notice to any area of the world of local or regional size. Phase III provided for enhancements and modifications to the system and was also completed in 1995. In FY96, CAST began providing maintenance and development tasks for NIDAS at both the unclassified and classified levels. In FY97, CAST was again funded by NAVOCEANO to develop software upgrades to NIDAS to enable NAVOCEANO to better produce data bases and products specific to Commander Mine Warfare Command.

For FY98, CAST was funded by NAVOCEANO for additional NIDAS development and maintenance at NAVOCEANO, Coastal Systems Station, COMINELWARCOM, and aboard the USS Inchon. Under this tasking CAST provided trouble shooting assistance for NAVOCEANO, COMINELWARCOM, and Coastal Systems Station personnel using NIDAS. Also, new versions of NIDAS were installed and tested at each of these locations. CAST also developed minor enhancements to the synthetic profile module, volume data applications, IDBMS interfaces, and MIW applications, as well as provided software upgrades for COMINELWARCOM. The final effort was to complete the final documentation for NIDAS3.

For FY99, in response to another NAVOCEANO statement of work, CAST has proposed to complete the following:

- Provide maintenance for approximately ten installations of NIDAS in NAVOCEANO spaces and two installations at COMINELWARCOM.
- Enhance NIDAS to recognize the highest security level of the data that is being displayed and apply the appropriate markings automatically.
- Enhance the "Axes Units" to allow users to specify data units.
- Implement the capability for "auto iso" while drawing a synthetic profile.
- Upgrade NIDAS to include a routine to ingest the Comprehensive Oceanographic and Atmospheric Data Set (COADS) data into the internal data base for any one or two COADS parameters. CAST will develop a capability to interactively edit COADS and to produce rapid response products. NIDAS was developed to edit, analyze, and generate products from MOODS. To optimize NIDAS for COADS, minor modifications will be accomplished as below.
- Upgrade NIDAS to develop a query menu to extract COADS data from the data base into memory for further processing.
- Upgrade NIDAS to implement a histogram algorithm to compute percent of observations versus magnitude of any single parameter.
- Upgrade NIDAS to implement a bivariate analysis algorithm to compute statistics for bivariate data such as: wind speed vs direction, wave height vs period, wave height vs direction, and any two parameters in COADS.
- Upgrade NIDAS to implement graphics routines for histograms and bivariate roses.
- Upgrade NIDAS to implement a capability to list and export to ASCII file including histograms in single tabular form and roses in a bivariate distribution table.
- Upgrade NIDAS to existing appropriate algorithms and graphics for MOODS data that will apply to COADS.
- Assess the magnitude of the effort to port various pieces of NIDAS to the Windows-NT environment, and draft an analysis report.
- Develop a prototype Windows-NT capability for LLT data with polygon, profile isolation, and export functions.
- Complete a Data Base Design Document/Software Design Document and updated NIDAS User Manual for NIDAS-4.
- As required by NAVOCEANO, all software and data formats will be "Year 2000" compliant.

NAVOCEANO in late FY98 has initiated a patent for NIDAS with the U.S. Patent Office. Developers include Mr. Steve Haeger of NAVOCEANO and CAST's Mr. Jim Corbin, Mr. Dharmesh Krishnamagaru, and Mr. Ramesh Krishnamagaru.

5.0 RESEARCH PROJECT WITH ENVIRONMENTAL PROTECTION AGENCY (EPA)

5.1 Software Infrastructure for Integrated Acquisition and Manipulation of Environmental Information (\$175K)

The EPA/Gulf of Mexico (GOM) Program Office (GMPO) is engaged in the protection of the environmental quality of the GOM region. At present, the program has four emphasis areas: (1) the prevention of adverse human health effects resulting from the consumption of raw shellfish; (2) reducing impact of human activity on fisheries due to pollution; (3) protecting and restoring Gulf habitats including coastal wetlands, aquatic vegetation, and offshore areas; and (4) protecting the Gulf from the deleterious effect of nutrient enrichment with the hypoxic zone on the Louisiana inner continental shelf. Addressing these complex issues involves collaboration with the five Gulf states, local governments, Federal agencies, and regional universities to collect, update and analyze data on the state of the GOM. Large amounts of data are collected having spatial scales varying from the watershed level to the Mississippi Sound, and temporal scales varying from days to decades. For efficient resource management, public policy, and information processing and dissemination for the outreach program, all data must be readily accessible, retrievable, and easily cross-correlated.

CAST was initially tasked in FY97 to establish an information infrastructure and to implement software based on a metadata database system to facilitate research, development, and management functionalities. Tasks completed included an analysis and visualization of Hypoxia Zone and shrimp landings, Gulf of Mexico bathymetry visualization, and the design, implementation, and Beta test of a Virtual Data Warehouse (VDW). The basic design requirements considered were: cost efficiency; moderate technical sophistication so that partners could participate without any significant effort or expense; no data storage duplication; and ease and efficiency for participation. With these guidelines, a proof-of-concept, Web-based prototype of the VDW was developed. The design was endorsed by the EPA Data and Information Transfer Committee (DITC). Since then CAST investigated possible database implementations; researched possible technologies for Web based database access; created a prototype database; implemented a prototype Web-based GUI; and developed a prototype Web-based database access system. The prototype VDW system consisted of a server with a RAID storage system providing capability to expand data capacity, memory, and computing power. CAST purchased two Pentium based PC's, one equipped with a RAID system to serve as a dedicated server, and the other to be used for software development.

In FY98 and continuing into FY99, CAST conducted a Beta-test of the VDW to incorporate recommended changes, and the second Beta test of the VDW is planned to start in the beginning of CY99. Tasks included:

- Set-up/maintenance of the VDW hardware and development of the Beta-test plan which have been completed.
- Conduct a Metadata Test. Six Beta testers participated in a telephone conference call held at the beginning of the Beta test. A live demonstration of the VDW was given during the call. The Beta testers were walked through the VDW using the interactive VDW Web GUI. The result of the conference call was satisfactory to all the participants but one, who did not have the compatible Web browser required to use the VDW. After the kick-off conference call, many comments were given by the Beta testers, and these were attached to the quarterly report. Based on the analysis of the feedback from the Beta-test, the VDW software was modified such that:
 - Its basic design requirements are cost efficiency, moderate technical sophistication so that users can participate without significant effort or expense, no data storage duplication, and ease and efficiency for participation.
 - It connects GMP participants via the Internet in a distributed virtual environment so that all participants can contribute and share information on the four GMP focus areas.
 - It links remotely distributed data sets via a metadata structure that is very close to the FGDC format. Efforts are currently being taken to ensure the fully compliance with the FGDC CSDGM (Content Standards for Digital Geospatial Metadata). The metadata provides a proxy at VDW for the actual data set residing at the participants site.
 - VDW provides a capability to transfer data sets directly to the user site when needed.
- There was also the issue of the many GMPO corporate datasets that exist and that need to be managed and archived. CAST performed some initial simulations with a limited, but representative, amount of data to provide guidance to GMPO on the scope of this issue. CAST also met with GMPO to identify their needs; researched the domain and the level of support that could be provided; and utilized the existing VDW system for a prototype demonstration.

- CAST also assisted and consulted with GMPO on scientific and technical issues related to this project, and attended relevant meetings and workshops.

For FY99 and continuing into FY00, CAST has proposed to accomplish the following four tasks:

- Task 1: Complete the development of the VDW and deliver the system to the GMPO. This will be accomplished in two phases. Phase I will provide for other VDW enhancements from the Beta Test (BT1). This includes modifying the VDW metadata record to include several more fields so as to make it FGDC metadata compatible. This in turn requires modification of the GUI, database structure, and server side software.

A major shortcoming of BT1 was that, in spite of the simplified VDW metadata format, few participants contributed to populating the VDW. The Beta testers were volunteers, and had no time to manually enter records for metadata that already resided in their systems. With the knowledge that most of the participant's metadata records were already in the FGDC format, CAST is planning to build a parser that will directly accept FGDC formatted metadata records and parse them into the VDW metadata format.

Phase II will provide for VDW completion and delivery to GMPO by 31 December 1999. Here CAST will perform a complete system test of the VDW. With the enhancements from Phase I, CAST/GMPO will conduct Beta Test 2 (BT2), where participants will be invited to exercise the VDW functionality, including the submission of metadata records in FGDC format, and querying and acquiring data sets via the VDW along with modifying and deleting the records. Feedback from this exercise will form the basis of the final system to be delivered. The recommended enhancements and modifications approved by GMPO will be implemented. The deliverables will include:

- The final VDW system with a fully documented software package, a user's manual, and a final technical report on the system.
- A tool for remotely accessing FGDC metadata records from participant sites. This reduces the participants' required effort by providing the addresses to access their metadata records, and the VDW operator can acquire the data records without any additional burden on the participant.
- A tool to automatically extract usage statistics.

-The performance of regular systems administration of the VDW DBMS and VDW website during this time period.

- Task 2: Implement and install the National Spatial Data Infrastructure (NSDI) Clearinghouse node and link the node with the VDW. On behalf of the GMPO, CAST competed for and was funded by the U.S. Geological Survey FGDC to develop an NSDI Clearinghouse Node. This task complements the VDW effort and allows the GMP to access and disseminate data at national levels. In this effort, CAST will link the VDW system with the NSDI node, provide documentation, conduct a demonstration, and populate the database with GMP metadata.
- Task 3: Perform a requirements study for a GMP Corporate Database Management System (GCDBMS) and the feasibility of its linkage with the VDW and the NSDI node. CAST will perform a requirements analysis for a system that will have an object oriented design and determine whether or not Oracle is the optimum database for the system. Oracle is fully capable from a technical point of view, but may not be the most cost effective choice for the GMPO. It is anticipated that the GMPO will own many data sets and will require a data archive and retrieval capability. CAST will perform a detailed requirements analysis for this. Several iterative interviews with GMPO managers and scientists will be conducted to determine the basic requirements and the general long-term scope of the GCDBMS. Based on these interviews, CAST will generate a preliminary requirements document for further deliberations with the GMPO. Following this, CAST will perform a technical requirement analysis generating a system requirement specification document. This document will include preliminary recommendations on system design approach; system hardware/software configuration; show the feasibility of the proposed system with a simple prototype development and demonstration; and include a follow-on proposal for the development of a full-fledged GCDBMS.
- Task 4: Perform a requirements study for the establishment of a Gulf Mortality Network (GMNET) System. CAST will perform a requirements analysis for the development and establishment of a GMNET database system. This system is intended to provide Gulf-wide information on marine organism mortality events in the Gulf, so that responsible parties can isolate, identify, and analyze the events and take any necessary remedial action. The full scope of the project has not yet been determined. CAST proposes to perform a complete requirements study, followed by a proposal for a complete implementation of the GMNET database system.

6.0 CURRENT FACILITIES AND PERSONNEL

CAST software has been developed using Sun Microsystems and Silicon Graphics Inc. Workstations and personal computers in a network configuration. The Windows NT, UNIX operating system, X-Windows client-server model, and the Open Software Foundation's Motif widget set are the cornerstones for the system. Much of the graphics is done using agX/Toolmaster from Advanced Visual Systems. The primary computer languages are C, C++, Fortran, X-Windows, and SGI proprietary GL and/or Open GL.

CAST is heavily invested in state-of-the-art computer hardware including an internal network of Sun Sparc (1's, 2's, 4's, 10s, and 20's) and SGI Indigo Extreme Graphics workstations and X-terminals, and personal computers. The network consists of a Sun Sparc 1000 Fileserver integrated with a magneto optical "jukebox" file storage system having a 180 gigabyte capacity on 144 internal platters, and six gigabytes of internal magnetic media storage. Remote users may access any systems on-line using the TELNET utility. Output can be routed to on-line optical disk and video tape recording equipment. Hard copy is available from a variety of printers. Additionally, all administrative and management staff are integrated into the local area network, utilizing a combination of networked MacIntosh and PC desktop computers.

At present, the Center consists of about fifteen permanent staff members including oceanographers, meteorologists, software engineers, fluid dynamicists, mathematicians, programmers, postdoctoral assistants, computer technicians, and administrative personnel. CAST typically supports 10 graduate and undergraduate students per year, and this has included students through the MSU Cooperative Education Program and Computer Science Department, as well as from several other universities including Southern Mississippi, New Orleans, Louisiana Tech, Virginia, South Dakota School of Mines, Oregon State, Louisiana State, Florida State, Brandeis, Tulane, William Carey, South Alabama, and Mississippi Gulf Coast Community College. CAST is located in Building 1103 of the Stennis Space Center, a major focal point of science, engineering, and technology efforts with nearly 3,500 employees.

APPENDIX

CAST PUBLICATIONS

Dietrich, D.E., A. Mehra, L.A. Yeske, and J.H. Corbin (1997). Modeling with Data Assimilation in the North Atlantic (DAMEE). ONR Annual Report on <http://www.omnet.com/onr/reports/home.cgi>, 30 October 1997, 5 pp.

V. Anantharaj, B. Shuvobroto, L.A. Yeske, and J.H. Corbin (1997). Applications of Numerical Models in the Coastal, Semi-Enclosed, and Marginal Seas Using the Relocatable Modeling Environment. ONR Annual Report on <http://www.omnet.com/onr/reports/home.cgi>, 30 October 1997, 5 pp.

Dietrich, D.E., A. Mehra, L.A. Yeske, and J.H. Corbin (1997). Modeling the Santa Barbara Channel Using Realistic Open Boundary Conditions and Winds. ONR Annual Report on <http://www.omnet.com/onr/reports/home.cgi>, 30 October 1997, 5 pp.

Corbin, J.H. and L.A. Yeske (1997). Development of Oceanographic Software Tools and Applications for Navy Operational Use. ONR Annual Report on <http://www.omnet.com/onr/reports/home.cgi>, 30 October 1997, 5 pp.

Shatzle, F. and J.H. Corbin (1997). Gulf Weather Corporation Receives SBA Award. The Sun Herald Newspaper-Business G-2, Biloxi, MS, 28 December 1997.

Dietrich, D.E., C.A. Lin, A. Mestas-Nunez, and D.-S. Ko (1997). A High Resolution Numerical Study of Gulf of Mexico Fronts and Eddies. Meteorology and Atmospheric Physics, 64, 187-201.

Shatzle, F. and J.H. Corbin (1998). SBA Honors Innovative Business. Coast Business, Gulfport, MS, 12-25 January 1998.

Mehra, A. and D.E. Dietrich (1998). Resolution and Parameter Sensitivity Studies in the North Atlantic Basin. Abstract Proceedings AGU Ocean Sciences Meeting, San Diego, CA, 9-13 Feb 1998.

Dietrich, D.E. and A. Mehra (1998). External and Local Wind Forcing of Santa Barbara Channel Circulation. Abstract Proceedings AGU Ocean Sciences Meeting, San Diego, CA, 9-13 Feb 1998.

Piacsek, S., P. Jayakumar, D.E. Dietrich, and A. Mehra (1998). Wind-Forced Transports Through the Mediterranean Straits. Abstract Proceedings AGU Ocean Sciences Meeting, San Diego, CA, 9-13 Feb 1998.

Abbott, C. (1998). Empress Manages Megabytes of MEL Archives at MSU CAST. Expressions Newsletter, VIII (1), Empress Software Inc., Greenbelt, MD, 1 March 1998, 1-2.

Zhou, M. And R.M. Passi (1998). Virtual Data Warehouse. MSU CAST Tech. Note 1-98, 10 March 1998, 12 pp.

Dietrich, D.E. and A. Mehra (1998). Explosive Convective Adjustment in a Hydrostatic Ocean Model. MSU CAST Tech. Report 2-98, 15 April 1998, 21 pp.

Dietrich, D.E. and A. Mehra (1998). A Semi-Implicit Free Surface Formulation for the Semi-Collocated Grid DieCAST Ocean Model. MSU CAST Tech. Report 3-98, 15 April 1998, 22 pp.

Mehra, A., R. Passi, L. Kantha, S. Payne, and S. Brahmachari (1998). Barotropic Tidal Predictions and Validation in a Relocatable Modeling Environment. MSU CAST Tech. Report 1-98 (Revised), 20 May 1998, 20 pp.

Corbin, J.H. (1998). Battle Space Awareness: Software Engineering and the Natural Environment. Proceedings of the 66th MORS (Military Operation Research Society) Symposium, Naval Postgraduate School, Monterey, CA, 23-25 June 1998.

Dietrich, D.E. (1998). Application of a Modified Arakawa "a" Grid Ocean Model Having Reduced Numerical Dispersion to the Gulf of Mexico Circulation. Dyn. Atm. Oceans, 27, 201-217.

Yeske, L.A., J.H. Corbin, V. Anantharaj, J. Chambless, and S. Foster (1998). Final Report Development of a Master Environmental Library (MEL) Client/Server Under Naval Research Laboratory Contract N00014-95-C-6032. MSU CAST Tech. Report 4-98, 1 July 1998, 50 pp.

Brahmachari, S. (1998). Users Manual for the Relocatable Modeling Environment (RME) and Graphical Information System Version 1.0. MSU CAST Tech. Report 5-98, 1 Sep 1998, 71 pp.

Yeske, L.A., J.H. Corbin, D.E. Dietrich, and A. Mehra (1998). Final Report: Modeling the Santa Barbara Channel Using Realistic Open Boundary Conditions and Winds. MSU CAST Tech. Report 6-98, 30 September 1998, 12pp.

Yeske, L.A., J.H. Corbin, D.E. Dietrich, and A. Mehra (1998). Final Report: Modeling with Data Assimilation in the North Atlantic (DAMEE). MSU CAST Tech. Report 7-98, 30 September 1998, 12pp.

Yeske, L.A., J.H. Corbin, D.E. Dietrich, and A. Mehra (1998). Final Report: Applications of Numerical Models in the Coastal, Semi-Enclosed, and Marginal Seas Using the Relocatable Modeling Environment. MSU CAST Tech. Report 8-98, 30 September 1998, 12 pp.

Yeske, L.A. and J.H. Corbin (1998). FY98 Research Program. MSU CAST Tech. Report 9-98, 30 September 1998, 52pp.

Yeske, L.A. (Editor) (1998). FY98 Student Research Projects. MSU CAST Tech. Note 2-98, 30 September 1998, 35pp.

Bowman, M.J., D.E. Dietrich, and C.A. Lin (1998). Observations and Modeling of Mesoscale Ocean Circulation Near Small Isolated Islands. Small Islands: Marine Sciences and Sustainable Development, AGU Coastal and Estuarine Studies Series, Edited by George Maul, (In Press).

Dietrich, D.E. and D.-S. Ko (1998). A Numerical Study of Shelfbreak Effects in the Western Gulf of Mexico. In Revision for Journal of Geophysical Research.

Dietrich, D.E., R. L. Haney, A. Mehra and S. Piacsek (1998). Comments on "A method for Improved Representation of Dense Water Spreading over Topography in Geopotential-Coordinate Models. In Revision for Journal of Physical Oceanography.

Zhu, Z., R.J. Moorhead, and A. Mehra (1998). Statistics of Eddy Dynamics in the NRL Layered Pacific Model Data. In Revision for Journal of Physical Oceanography.

Bowman, M., D.E. Dietrich, and P. Mladenov (1998). Two Predictive Studies of Coastal Ocean Circulations: Doubtful Sound, New Zealand, and Barbados, West Indies. Invited Contribution to Appear in: Coastal Ocean Prediction, C.N.K. Mooers, Editor. Coastal and Estuarine Studies, AGU. (Under Review).

Dietrich, D.E. (1998). Reynolds Number and Resolution Sensitivity Studies with Gulf of Mexico Eddies. Journal of Geophysical Research. (Under Review.)

Mehra, A. and D.E. Dietrich (1998). Modeling of the North Atlantic Basin Using the DieCAST Ocean Model. Deep Sea Research, (Submitted).

Dietrich, D.E. and A. Mehra (1998). Sensitivity Studies in the Santa Barbara Channel Using DieCAST. MSU CAST Tech. Note 3-98 (In Preparation).

CAST PRESENTATIONS AND DEMONSTRATIONS

Dietrich, D.E. (1997). North Atlantic Modeling using DieCAST. Seminar and Presentation to Los Alamos National Laboratory Modelers, Los Alamos, NM, 17 October 1997.

Dietrich, D.E. (1997). Gulf of Mexico Modeling using DieCAST. Presentation to ONR Program Managers and Academic Ocean Modelers, Washington, DC, 12 November 1997.

Corbin, J.H., M. Zhou, and R.M. Passi (1997). Virtual Data Warehouse Application. Presentation to EPA/GMPO Director and Staff at FY97 CAST Performance Review, Stennis Space Center, MS, 18 November 1997.

Corbin, J.H. and M. Zhou (1997). Virtual Data Warehouse Application. Presentation to EPA/GMPO Virtual Data Warehouse Working Group, Stennis Space Center, MS, 1 December 1997.

Corbin, J.H. (1998). Relocatable Modeling Environment for Tides. Presentation and Demonstration to National Ocean Partnership Program FY98 Proposal Team of USM Robert Willems, PSI Richard Crout, NRL John Harding, NAVOCEANO Joe Stinus, NRL Ruth Prellor, and Dr. Jim Lewis, Stennis Space Center, MS, 9 January 1998.

Corbin, J.H. and R.M. Passi (1998). CAST Software Applications. Presentation and Demonstration to National Ocean Partnership Program Personnel Rear Admiral Brad Mooney and Dr. Rick Spinrad, Stennis Space Center, MS, 13 January 1998.

Bowman, M.J., D.E. Dietrich, A. Mehra, E. Soye, and O. Ross (1998). Numerical Simulations of Colliding Anticyclonic Eddies in the East Australian Current (EAC). Poster Presentation, AGU Ocean Sciences Meeting, San Diego, CA, 9-13 February 1998.

Dietrich, D.E. and A. Mehra (1998). External and Local Wind Forcing of Santa Barbara Channel Circulation. Santa Barbara Channel Minerals Management Service/ONR Quarterly Review Board #5, San Diego, CA, 4-6 February 1998.

Corbin, J.H. and R.M. Passi (1998). Relocatable Modeling Environment (RME) in the Yellow Sea. Presentation and Demonstration to NAVOCEANO's Drs. William Jobst and Martha Head, Stennis Space Center, MS, 17 February 1998.

Corbin, J.H. and L.A. Yeske (1998). CAST Research Program-Present and Planned. Presentation to MSU External Review Advisory Committee, Mississippi State, MS, 20 March 1998.

M. Zhou (1998). CAST Role in U.S. Geological Survey National Spatial Data Infrastructure (NSDI) Program. Presentation to U.S. Geological Survey Federal Geographic Data Committee at NSDI Partnerships Workshop, Charleston, SC, 22 September 1998.

Dietrich, D.E. (1998). The Use of DieCAST in Modeling the Adriatic Sea. Presentation at ONR Workshop on Oceanography of the Adriatic Sea, Trieste, Italy, 24 September 1998.

OFFICES HELD BY CAST PERSONNEL

The CAST Director was a member of Commander Naval Meteorology and Oceanography Command Shallow Water Model Assessment Review Panel.

The CAST Director was appointed to the Board of Governors for the Consortium for Oceanographic Research and Education (CORE) and represented MSU at periodic meetings of CORE.

The CAST Director was a member of the ONR Naval Ocean Modeling and Prediction Program Ad Hoc Modeling Advisory Panel.

SEMINARS SPONSORED BY CAST

<u>Name/Institution</u>	<u>Title</u>	<u>Date</u>
Dr. Lakshmi Kantha Univ. of Colorado	Real-Time Operational Nowcasts and Forecasts in Marginal Seas: A Feasibility Study in the Gulf of Mexico to Commander Naval Meteorology and Oceanography Command RADM K. Barbour, Technical Director Dr. D. Durham, and CNMOC Staff	5 January 1998 Stennis Space Ctr
Dr. Lakshmi Kantha Univ. of Colorado	Real-Time Operational Nowcasts and Forecasts in Marginal Seas: A Feasibility Study in the Gulf of Mexico to Commander Naval Oceanographic Office CAPT L. Warrenfeltz, Technical Director L. Bernard, and NAVO Staff	6 January 1998 Stennis Space Ctr

PROFESSIONAL AWARDS TO CAST PERSONNEL

To Charlene Carroll and Joan Pritchett, MSU Office of Research, for Outstanding Support to CAST, 29 October 1997.

To Lynda Tuck and Tina Henson, MSU Office of Sponsored Programs Administration, for Outstanding Support to CAST, 29 October 1997.

To Ming Zhou, Recipient of 1998 Mississippi State University Centers and Institutes Research Support Award, 27 Feb 1998.

To Midge Wilson, Nominated for MSU Zacharias Distinguished Staff Award, 13 April 1998.

To James Corbin, Lanny Yeske, Steve Foster, Val Anantharaj, David Dietrich, and Midge Wilson, MSU Employee Recognition-Five Years Service, 1 May 1998.

CAST PARTICIPATION IN INTERDISCIPLINARY ACTIVITIES

With Mississippi State University:

- The Cooperative Education Program. CAST employed MSU Cooperative Education student, Mr. Brandon Jockman, during this period. CAST also recruited students during MSU Fall Interview Days in October 1997.
- The Scientific and Technical Research Center (STRC). Here CAST worked closely with Dr. Roy Crochet in the coordination of joint MSU activities at the Stennis Space Center. We also jointly operated a motor vehicle for use at the Stennis Space Center.
- The Research Director's Council. The CAST Director was a member of this council.
- The Mississippi Research Consortium. This interaction involved the awarding of three contracts to CAST from the Naval Oceanographic Office, issued as NASA delivery orders through the Consortium. One other contract is pending approval.

Other Universities/Academia:

- University of Southern Mississippi Cooperative Education Program. CAST employed USM students Mr. Min Zhang, Mr. Shengyong Li, Mr. Mike Zhou, Mr. Sayantan Ganguly, Ms. Pat Ehrensing, Mr. Rohit Mehra, and Ms. Alice Qiao to assist in software engineering. In addition, Mr. Steven Blum a graduate of USM was hired as a temporary laboratory aide to assist in software engineering.
- Mississippi Gulf Coast Community College. CAST employed Mr. Gabriel Murchison to support our computer maintenance/upgrade program.
- Florida State University. CAST employed Mr. Colin Murray to assist in the ocean modeling research program.
- University of Colorado. CAST was involved in a collaborative effort with Dr. Lakshmi Kantha to develop a relocatable modeling environment for both tidal and circulation models.
- Florida State University. Dr. Richard Pffefer collaborated with CAST to use DieCAST in modeling hurricane interactions on the continental shelf.

- Tulane University. Dr. Boumediene Belkouche collaborated with CAST in database research in support of the EPA's Virtual Data Warehouse Project.
- Texas A&M University. Dr. Worth Nowlin collaborated with CAST in using DieCAST for general modeling of the Gulf of Mexico.
- Oregon State University. Dr. James Richman worked with CAST to develop a Southern Hemisphere version of DieCAST which has produced excellent results at 1/3 degree resolution.
- Massachusetts Institute for Technology and Canadian Meteorological Center. Dr. Kerry Immanuel collaborated with CAST in coupling DieCAST to the Canadian operational meteorological model.
- Massachusetts Institute for Technology. CAST collaborated with Mr. Robert Fadel in submitting a Littoral Oceanographic and Atmospheric proposal to ONR under the National Oceanographic Partnership Program.
- Consortium for Oceanographic Research and Education (CORE). CAST collaborated with Admiral James Watkins and Dr. Robert Spinrad of this Consortium whose purpose is to advance the science of oceanography. MSU is a voting member of CORE with the CAST Director the MSU representative on the Board of Governors.

Navy:

- Office of Naval Research. CAST received research grants in the areas of High Resolution Modeling of the Santa Barbara Channel, Modeling with Data Assimilation in the North Atlantic, and Relocatable Numerical Models in Coastal Seas.
- Naval Research Laboratory-Stennis Space Center, MS. CAST worked with Drs. Steve Piascek and Ruth Prellor in Arctic Ocean modeling and the coupling of DieCAST to the NRL ice model. Dr. Dietrich also collaborated with Dr. Piascek in high resolution modeling of the Mediterranean. Also, Drs. Harley Hurlburt and Charles Barron used DieCAST in Gulf of Mexico simulations of the LATEX region.
- Commander Naval Meteorology and Oceanography Command (CNMOC) Shallow Water Model Assessment Panel. The CAST Director is a member of this panel that reviews the status of ocean modeling and makes recommendations on which models should be transitioned to the Navy.

- Naval Oceanographic Office. CAST provided development support for the Naval Interactive Data Analysis System (NIDAS) to this office and Commander Mine Warfare Command. NAVOCEANO in late FY98 has initiated a patent for NIDAS with the U.S. Patent Office. Developers include Mr. Steve Haeger of NAVOCEANO and CAST's Mr. Jim Corbin, Mr. Dharmesh Krishnamagaru, and Mr. Ramesh Krishnamagaru.
- Naval Postgraduate School. Dr. Robert Haney collaborated with CAST and funded Dr. Dietrich in modeling the California Current (Santa Barbara Channel) using DieCAST. In addition, Dr. Alvaro Viudez ran DieCAST in the Western Mediterranean to study the dynamics of a major semi-permanent anticyclonic gyre.

Other Federal Government:

- Defense Modeling and Simulation Office. CAST worked with several federal government agencies in developing sites for the Master Environmental Library which included: NRL-Monterey, CA; MSU CAST-Stennis Space Center, MS; Air Force Weather Agency-Omaha, NE; Air Force Combat Climatology Center-Asheville, NC; National Geophysical Data Center-Boulder, CO; Army Research Laboratory-White Sands, NM; National Imagery and Mapping Agency-Fairfax, VA and St. Louis, MO; and the Air Force Simulator Database Facility-Kirkland, WA. Approved as future MEL sites are the Naval Oceanographic Office-Stennis Space Center, MS and the Army Topographic Engineering Center-Alexandria, VA. Approved as Mel candidate sites are the Air Force Research Laboratory-Hanscom, MA; Army Research Laboratory-Adelphi, MD; Army Waterways Experiment Station Coastal Hydraulics Laboratory-Vicksburg, MS; and the Seventh Army Training Command Terrain Simulator Center-Grafenwoehr, Germany.
- NOAA National Marine Fisheries Service. Dr. David Dietrich worked with this agency and Dr. Pat Tester in DieCAST GOM model algae bloom simulations.
- NOAA Great Lakes Environmental Research Laboratory. Drs. David Schwab, Dmitry Beletsky, and William O'Connor collaborated with CAST in conducting simulations of internal Kelvin Waves and coastal upwelling in the Great Lakes.
- Environmental Protection Agency Gulf of Mexico Program Office. CAST worked with this Stennis Space Center based office and received a research grant to develop software infrastructure for EPA data. Collaboration also was

achieved in developing a successful proposal to the U.S. Geological Survey for development of a National Geospatial Data Clearinghouse Node at CAST.

- U.S. Geological Survey. CAST was awarded a contract by this agency for the development of a National Geospatial Data Clearinghouse Node in FY99.

Business and Industry:

- Gulf Weather Corporation. CAST worked with this company in a Phase II contract under the Department of Defense Small Business Innovative Research Program for a Meta-Database for Ocean Imagery.
- Planning Systems, Inc. CAST has a five-year subcontract with PSI to support the Naval Research Laboratory Environmental Acoustics Program. This contract was awarded in August 1994, but no delivery orders have been issued.
- Physitron, Inc. CAST collaborated with this Huntsville, Alabama business in the development of the Weather Watch briefing application. Physitron is also a subcontractor to CAST for the Master Environmental Library.
- Weather New, Inc. Dr. Zhifan Zhu of this Sunnyvale, California based company was a consultant to CAST to modify the Environmental Visualization Software Version 20 into functional modules for use at CAST.
- Rela, Inc. Mr. Michael Carpenter of this Boulder, Colorado based company was a consultant to CAST to add data assimilation to the DieCAST Model.

International:

- New Zealand Electric Company. This company collaborated and funded Dr. David Dietrich for high resolution modeling studies of Doubtful Sound and other coastal areas of New Zealand using DieCAST.
- Australian Defense Forces Academy. Dr. Cliff Hearn in Canberra collaborated with CAST in using DieCAST to run simulations in the Hawaiian Island area. Dr. Michael Laurs, Director of the NOAA Fisheries Laboratory in Honolulu is also using DieCAST as the Hawaiian Regional Model.
- Australian Bureau of Meteorology. Dr. Brian Sanderson in Melbourne collaborated with CAST is using DieCAST to run high resolution simulations in the Australian Current and the Tasman Sea.

- Auckland University. Students, Mr. Oliver Ross and Mr. Eric Soyes, of the School of Environmental and Marine Sciences used and applied DieCAST as a New Zealand Regional Prediction Model.
- Dalhousie University. Dr. Keith Thompson and Dr. Jinju Sheng collaborated with CAST to add data assimilation to DieCAST for application in the Gulf of Saint Lawrence and the Grand Banks.
- McGill University, Dr. Charles Lin collaborated with CAST in the use of DieCAST for global climate research and convection studies.
- Bedford Institute of Oceanography. Dr. Dan Wright in Nova Scotia employed DieCAST for eddy resolving North Atlantic climate studies.
- Memorial University. Dr. Richard Greatbatch in Newfoundland used DieCAST for high resolution modeling of the Labrador Sea and Newfoundland Bay.
- James Cook University. Dr. Lance Bode collaborated with CAST to nest the DieCAST Coral Sea model in a DieCAST Global Ocean model.
- Environment Canada. In February 1996, CAST's Senior Research Assistant Mr. Valentine Anantharaj, was assigned to Environment Canada in Vancouver, British Columbia, in a collaborative effort to develop the next generation database management tools to support environmental research and operations.
- University of Trieste. CAST collaborated with Dr. Roberto Purini of Trieste, Italy in ultra-high resolution modeling of the Adriatic Sea. Dr. Dietrich also participated in an Adriatic Sea Modeling Workshop held in Trieste.
- University of New South Wales. Collaboration continued with Dr. Brian Sanderson in Sydney using the Australian Regional Model for studies of subgrid eddy dynamics
- UIB, Palma, Majorca. CAST worked with Dr. Juachim Tintore in modeling of the Alboran Sea Region of the Mediterranean.
- University of Otago. CAST collaborated with Dr. Stephen Wing in using DieCAST to study sea urchin larvae transport in the New Zealand South Island Fjordland National Park. This collaboration also extended to Dr. Philip Mladinov, Chairman of Marine Sciences, and with Ph.D. candidate Mr. Darryl Coup on DieCAST model applications in Doubtful Sound.

- CSIRO-Australia. CAST collaborated with Dr. John McGregor on applying DieCAST to the CSIRO Climate Modeling Program.
- NIWA-New Zealand. CAST worked with Dr. Rob Murdock, Director of Physical Oceanography at NIWA on DieCAST applications.
- Government of Bulgaria. Cast collaborated with Dr. Emil Stanev in applying the DieCAST Model to the Black Sea.
- Russian Federation. CAST collaborated with Drs. Konstantin Korotenko, Director of the Shirshov Institute of Oceanology in Moscow, and Ivan Obshinnikov in using the DieCAST Model in the Black Sea.

OTHER WORKSHOPS AND MEETINGS ATTENDED BY CAST

<u>Name</u>	<u>Title</u>	<u>Dates/Location</u>
J.H. Corbin R.M. Passi	Planning Meeting with Dr. Lakshmi Kantha of the University of Colorado and NAVOCEANO's Dr. Martha Head on RME Applications	3 October 1997 Stennis Space Ctr, MS
J.H. Corbin	Board of Governors Annual Meeting of the Consortium for Ocean Research and Education	7 October 1997 Washington, DC
CAST Staff	Presentation by Mr. Steve Haegar of NAVOCEANO on the NIDAS Application and Patent Information	7 October 1997 Stennis Space Ctr, MS
CAST Staff	Benefits Meeting and Selection with MSU Human Resources Management Ms. Ann Bell	14 October 1997 Stennis Space Ctr, MS
J.H. Corbin F.Schatzle	Presentation of Tibbett's Award for Outstanding Small Business Innovative Research Project in Mississippi	15-16 October 1997 Washington, DC
M.S. Foster J.W. Chambless	Conduct Interviews at MSU Coop-Education Fall Interview Days	15-16 October 1997 Mississippi State, MS

D.E. Dietrich	Seminar on Modeling the North Atlantic Using DieCAST	17 October 1997 Los Alamos, NM
J.H. Corbin	MEL Long-Range Planning Meeting	21-23 October 1997 Washington, DC
M.S. Foster	Attend Commander Naval Oceanography and Meteorology Command Change of Command	23 October 1997 Biloxi, MS
J.H. Corbin L.A. Yeske	Progress and Status Meeting with MSU Director Centers and Institutes	28 October 1997 Mississippi State, MS
J.H. Corbin L.A. Yeske E. Lott M. Wilson	Presentation of Awards to Charlene Carroll, Joan Pritchett, Lynda Tuck and Tina Henson	29 October 1997 Mississippi State, MS
J.W. Chambless M. Zhou	Discussions with NRL Program Managers on MEL Design and Future Directions	11-15 November 1997 Monterey, CA
D.E. Dietrich	Discussions with ONR and Academic Ocean Modelers on Gulf of Mexico Nowcasting/Forecasting	12 November 1997 Washington, DC
J.H. Corbin L.A. Yeske	Meeting with MSU Vice President for Research and Director Centers and Institutes on CAST Status	13 November 1997 Stennis Space Ctr, MS
J.H. Corbin R.M. Passi M. Zhou	EPA/GMPO Contract FY97 CAST Performance Review	18 November 1997 Stennis Space Ctr, MS
J.H. Corbin	MEL Planning Meeting with CNO Executive Agent Dr. Donna Blake	20 November 1997 Stennis Space Ctr, MS
J.H. Corbin M.Zhou	Discussions on VDW Project with EPA/GMPO Working Group	18 November 1997 Stennis Space Ctr, MS
J.H. Corbin M.S. Foster	Neptune Science's Capabilities and Demonstration Open House	2 December 1997 Slidell, LA

J.H. Corbin L.A. Yeske	Discussion with USM's Robert Willems, PSI's Richard Crout, and Dr. Jim Lewis on National Ocean Partnership Program Proposal	9 December 1997 Stennis Space Ctr, MS
V. Anantharaj J.W. Chambless J.H. Corbin	MEL Progress Meeting with Mr. Chuck Stein, NRL Monterey	9-10 December 1997 Stennis Space Ctr, MS
L.A. Yeske	Discussion with Mr. Russell Foster MSU Engineering College Services Coordinator on Off-Campus Graduate Programs	9 December 1997 Stennis Space Ctr, MS
J.H. Corbin L.A. Yeske M.S. Foster C. Abbott S.W. Payne J.W. Chambless	Attend NAVOCEANO Sponsored Information Security Briefing Conducted by Criminal Investigative Service and the Federal Bureau of Investigation	10 December 1997 Stennis Space Ctr, MS
S.W. Payne C. Abbott	Workshop on Troubleshooting and Maintaining Personal Computers	11-12 December 1997 New Orleans, LA
J.H. Corbin R. M. Passi	Relocatable Modeling Environment Planning Meetings with Dr. Lakshmi Kantha of University of Colorado	5-6 January 1998 Stennis Space Ctr, MS
J.H. Corbin R. M. Passi	Relocatable Modeling Environment Planning Meetings with Dr. Lakshmi Kantha, Dr. Martha Head, and Dr. John Harding	7 January 1998 Stennis Space Ctr, MS
J.H. Corbin R.M. Passi M. Zhou	Meeting on RME Applications for NOPP with NAVOCEANO's Mr. Joe Stinus, NRL's Ruth Prellor, and Dr. Jim Lewis	9 January 1998 Stennis Space Ctr, MS
J.H. Corbin R.M. Passi	Meeting on CAST Software Research Applications for NOPP to RADM Brad Mooney and Dr. Rick Spinrad	13 January 1998 Stennis Space Ctr, MS

R.M. Passi	Meeting with EPA/GMPO Personnel on USGS Proposal	14 January 1998 Stennis Space Ctr, MS
J.H. Corbin R. M. Passi	Meeting on SBIR Phase III Funding and Endorsement from SPAWARS Dr. Steve Payne and Gulf Weather Corporation's Mr. Frank Schatzle	26 January 1998 Stennis Space Ctr, MS
J.H. Corbin	Space and Naval Warfare Systems Command NRL Program Review	26-30 January 1998 Stennis Space Ctr, MS
J.H. Corbin	Meeting with SPAWARS CAPT C. Hopkins and Dr. S. Payne, and Mr. Frank Schatzle on SBIR Phase III Sponsorship	28 January 1998 Stennis Space Ctr, MS
J.H. Corbin L.A. Yeske M.S. Foster	CAST Status Meeting with Dr. Clay Taylor, MSU Director of Centers and Institutes	3 February 1998 Mississippi State, MS
J.H. Corbin L.A. Yeske M.S. Foster M. Wilson	MSU Research Administration Workshop and Discussions with Comptroller and Sponsored Programs Personnel	4 February 1998 Mississippi State, MS
D.E. Dietrich A. Mehra	ONR Quarterly Review Meeting on Santa Barbara Channel Modeling	4-6 February 1998 La Jolla, CA
CAST Staff	Introductory Meeting with MSU President Malcolm Portera	5 February 1998 Stennis Space Ctr, MS
D.E. Dietrich A. Mehra	American Geophysical Union Ocean Sciences Meeting	9-13 February 1998 San Diego, CA
J.H. Corbin M.S. Foster M. Zhou J.W. Chambliss	Department of Defense Basic Configuration Management Training for MEL by Mr. Roger Huff of Mar, Inc.	10 February 1998 Stennis Space Ctr, MS
J.H. Corbin J.W. Chambliss M. Zhou	Meeting with Logic Works' Ms. Anne Briggs and Mr. Joe Potter on Potential Collaboration	16 February 1998 Stennis Space Ctr, MS

C. Abbott	Meeting on NIDAS Maintenance and Development with Commander Mine Warfare Command Personnel	16-20 February 1998 Corpus Christi, TX
J.H. Corbin R. M. Passi	Meeting on RME Yellow Sea with NAVOCEANO's Drs. William Jobst, Martha Head, Robert Carter, and WSC Staff	17 February 1998 Stennis Space Ctr, MS
J.H. Corbin L.A. Yeske M. Wilson	Discussions with MSU Sponsored Programs Administrator Ms. Tina Henson	17 February 1998 Stennis Space Ctr, MS
J.H. Corbin S.W. Payne	Discussions with Dr. Lakshmi Kantha on RME Applications	7 February 1998 Stennis Space Ctr, MS
L.A. Yeske R. M. Passi M. Zhou	Meeting with EPA GMPO's Dr. Eugene Meier and Mr. James Matthews on Joint Proposal to U.S. Geological Survey	19 February 1998 Stennis Space Ctr, MS
S. Brahamachari	Annual Meeting of the Mississippi Academy of Sciences	26 February 1998 Biloxi, MS
R.M. Passi M. Zhou	Meeting with EPA GMPO's Mr. James Matthews on VDW Beta-test Plan	3 March 1998 Stennis Space Ctr, MS
A. Mehra	Data Assimilation and Model Evaluation Experiment North Atlantic Project Review Meeting	4-6 March 1998 Miami, FL
J.H. Corbin L.A. Yeske	Meeting with Dr. Charles Calvo, Dr. John Miller, and Associates on NOPP COAST Contract	19 March 1998 Mississippi State, MS
J.H. Corbin L.A. Yeske	Status Report Meeting with Dr. Clayborne Taylor, Director Centers and Institutes	19 March 1998 Mississippi State, MS

J.H. Corbin L.A. Yeske	MSU External Review Advisory Committee Meeting on CAST Research and Operations	20 March 1998 Mississippi State, MS
J.W. Chambless V. Anantharaj Y. Lau S. Bhate M. Zhou	Master Environmental Library Developers Meeting	23-25 March 1998 Monterey, CA
CAST Staff	Director's Staff Meeting	2 April 1998 Stennis Space Ctr, MS
S.W. Payne	Sun Systems Technology Update and Demonstration	7 April 1998 Stennis Space Ctr, MS
V. Anantharaj	Meeting with MEL Program Manager Dr. Richard Siquig	13-16 April 1998 Monterey, CA
S. McDaniel	Banner Training by Ms. Sue Benedict of MSU Human Resources Management	17 April 1998 Stennis Space Ctr, MS
J.W. Chambless M. Zhou	Fourth Annual Conference on Object-Oriented Technology and Systems (COOTS '98)	27 Apr - 1 May 1998 Santa Fe, NM
R. Passi M. Zhou	Discussions with EPA GMPO's Ms. Larinda Norton, Dr. Gene Meier, and Dr. Fred Kopfler on GOM Hypoxia Research	7 May 1998 Stennis Space Ctr, MS
A. Mehra J. Chambless C. Abbott S. Brahmachari M. Zhou	Internal CAST Mid-Year Review of ONR, MEL, NIDAS, RME, and EPA Projects	11 May 1998 Stennis Space Ctr, MS
L. Yeske	Meeting with Mr. Rusty Foster, MSU Engineering Department on Graduate Education at SSC	12 May 1998 Stennis Space Ctr, MS

M.Wilson	MSU Internal Audit of CAST Credit Card Procedures by Ms. Tonya Chamberlain	12 May 1998 Stennis Space Ctr, MS
J.H. Corbin R.M. Passi M. Zhou L. Yeske	Progress Review with EPA GMPO Director Mr. James Giatinna and Deputy Director Mr. Bryon Griffith	13 May 1998 Stennis Space Ctr, MS
J.H. Corbin L. Yeske	Discussions with Mr. Matt Ronning, Director of Sponsored Programs Administration on Proposal Procedures	19 May 1998 Stennis Space Ctr, MS
J.H. Corbin L. Yeske	Discussions with Mr. Mark McGee of MSU Office of Research	19 May 1998 Stennis Space Ctr, MS
S.W. Payne	USENIX Annual Technical Training in Systems Administration	25-28 May 1998 New Orleans, LA
J. Chambless	USENIX Annual Technical Training in UNIX Programming	25-28 May 1998 New Orleans, LA
J.H. Corbin	Discussions with Dr. Peter Ranelli of PET Program on Space Plans for Building 1103 at SSC	29 May 1998 Stennis Space Ctr, MS
J.H. Corbin	Discussions with Dr. Melvin Ray on Building 1103 Space Plans	4 June 1998 Stennis Space Ctr, MS
D.E. Dietrich	Meetings with Dr. Charles Lin, McGill University	8-12 June 1998 Montreal, Canada
J.H. Corbin	Meeting on Integrating FNMOC Data into MEL with NRL, NAVOCEANO, and FNMOC Personnel	11 June 1998 Stennis Space Ctr, MS
J.H. Corbin	Meeting with Mr. David Geiger on United Way of Mississippi/ Combined Federal Campaign	19 June 1998 Stennis Space Ctr, MS

R.M. Passi	Discussions with EPA GMPO's Dr. Eugene Meier and Mr. James Matthews on VDW Follow-On Research	22 June 1998 Stennis Space Ctr, MS
J.H. Corbin	66th Military Operations Research Society (MORS) Symposium	22-25 June 1998 Monterey, CA
J.H. Corbin	Meeting with Dr. Richard Siquig on MEL FY99 Planned Funding	22-25 June 1998 Monterey, CA
J.H. Corbin R. M. Passi	Meeting with NaVOCEANO's Dr. Mike Carron and Mr. Steve Haeger on Future RME Research	29 June 1998 Stennis Space Ctr, MS
D.E. Dietrich	Collaborative Discussions with Various Academic and Government Ocean Modelers	1 July-15 August 1998 Australia/New Zealand
R. Mehra P. Ehrensing S. Li M. Zhou B. Jockman A. Mehra	Training on Unix Motif/X-Windows by MSU CAST's Mr. Clifton Abbott	7 & 14 July 1998 Stennis Space Ctr, MS
J.H. Corbin L.A. Yeske	Discussions with Ms. Lynn Randle MSU Sponsored Programs Development Specialist	14 July 1998 Stennis Space Ctr, MS
J.H. Corbin	Discussion with NRL Legal Counsel Mr. Armand Beede on NIDAS Patents	15 July 1998 Stennis Space Ctr, MS
J.H. Corbin M. Zhou	Discussions with EPA GMPO Project Managers on Data Transfer Procedures	20 July 1998 Stennis Space Ctr, MS
S. McDaniel	Kick-Off Meeting on United Way Mississippi/Combined Federal Campaign	22 July 1998 Stennis Space Ctr, MS

S. Bhate	Participate in Siggraph '98 Conference	20-23 July 1998 Orlando, FL
J.H. Corbin L.A. Yeske	Discussions with Dr. Robert Altenkirch, MSU Vice President for Research and Ms. Tina Henson of Sponsored Programs Admin	29 July 1998 Mississippi State, MS
L.A. Yeske	Discussion with Mr. Matt Ronning Director of Sponsored Programs Administration	29 July 1998 Mississippi State, MS
J.H. Corbin L.A. Yeske	Participated in Monthly Meeting of MSU Directors of Centers and Institutes	29 July 1998 Mississippi State, MS
V. Anantharaj	Environment Canada Planning Retreat	6-7 August 1998 Vancouver, Canada
R. M. Passi	Discussion with EPA GMPO's Dr. Eugene Meier on FY99 Planned Funding	10 August 1998 Stennis Space Ctr, MS
J.H. Corbin M. Zhou	Discussions with EPA GMPO's Director James Giatinna and Deputy Director Bryon Griffith on VDW Follow-On Research	11 August 1998 Stennis Space Ctr, MS
V. Anantharaj	Participated in Graphics Communications Association (GCA) Annual Conference	18-19 August 1998 Montreal, Canada
L.A. Yeske	Discussion with Mr. James Matthews on FY99 Proposal to EPA Gulf of Mexico VDW	19 August 1998 Stennis Space Ctr, MS
J.H. Corbin L.A. Yeske	Discussion with Mr. Steve Haeger of NAVOCEANO on NIDAS Funding for FY99	19 August 1998 Stennis Space Ctr, MS
V. Anantharaj	Attend GCA's Extensibile Markup Language Tutorial/Workshop	20-21 August 1998 Montreal, Canada

J.H. Corbin	Discussion with Dr. Boumediene Belkouche of Tulane University on EPA VDW Collaboration	15 September 1998 Stennis Space Ctr, MS
L.A. Yeske J.H. Corbin	Discussions with Dr. Robert Altenkirch, MSU Vice President for Research	15 September 1998 Stennis Space Ctr, MS
M. Zhou	Discussion with EPA GMP's Mr. Bryon Griffith and Mr. James Matthews on Proposed Corporate Database Research	16 September 1998 Stennis Space Ctr, MS
D.E. Dietrich	Attend ONR Workshop on Oceanography of the Adriatic Sea	21-25 September 1998 Trieste, Italy
M. Zhou	Participate in U.S. Geological Survey FGDC "NSDI Partnerships Workshop"	22-24 September 1998 Charleston, SC

CAST PROPOSALS SUBMITTED AND CONTRACTS AWARDED

	<u>To</u>	<u>Title</u>	<u>Submitted</u>	<u>Amount Requested</u>	<u>Amount Awarded</u>
a.	Naval Research Laboratory Environmental Acoustics via Planning Systems, Inc. Slidell, LA	PI: J. Corbin Environmental Acoustics Support - CAST is a Subcontractor to PSI	16 May 94	\$35,000 Per Year	No Work Orders Issued in FY98
b.	Office of Naval Research Navy Ocean Modeling and Prediction Program Office Arlington, VA	PI: D.E. Dietrich Modeling with Data Assim in the North Atlantic (DAMEE)	28 Jun 96	\$200,000	\$100,000 for FY98
c.	Office of Naval Research Navy Ocean Modeling and Prediction Program Office Arlington, VA	PI: D.E. Dietrich Modeling the Santa Barbara Channel with Realistic BC and Winds	28 Jun 96	\$190,000	\$100,000 for FY98
d.	Office of Naval Research Navy Ocean Modeling and Prediction Program Office Arlington, VA	PI: V. Anantharaj Relocatable Modeling Environment for Coastal Seas	28 Jun 96	\$200,000	\$100,000 for FY98
e.	Environmental Protection Agency Program Office Stennis Space Center, MS	PI: R. Passi Support for Gulf of Mexico Program Office	9 Dec 96	\$100,000	\$100,000 for FY97/98

f.	Naval Oceanographic Office via the Mississippi Research Consortium and NASA Stennis Space Center, MS	PI: S. Payne Tides Relocatable Model Environment for the Yellow Sea	16 Apr 97	\$137,000	\$89,000 for FY97/98
g.	Naval Oceanographic Office via the Mississippi Research Consortium and NASA Stennis Space Center, MS	PI: C. Abbott Naval Interactive Data Analysis System (NIDAS) Development/Maintenance for COMINEWARCOM Upgrades II	16 Jun 97	\$41,500	\$42,000 for FY98
h.	Naval Oceanographic Office via the Mississippi Research Consortium and NASA Stennis Space Center, MS	PI: C. Abbott Naval Interactive Data Analysis System (NIDAS) Development/Maintenance for COMINEWARCOM	10 Jul 97	\$71,500	\$75,000 for FY98
i.	Naval Research Laboratory Code 7540: Dr. Ted Tsui Monterey, CA	PI: V. Anantharaj, J. Corbin, J. Chambless, and A. Matiyevsky Advanced Development of MEL FY98-00	24 Jul 97	\$3,210,713 Total Award FY98-00	\$534,778 for FY98
j.	Naval Oceanographic Office Stennis Space Center, MS	PI: J.H. Corbin Preproposal Common Environment for Model Evaluation, Transition, and Operation FY98-99	7 Aug 97	\$398,649	Not Awarded to CAST
k.	DOD Small Business Innovative Research Pro- gram via Gulf Weather Corporation Stennis Space Center, MS	PI: J. Corbin Metadata Base for Auto Oceanographic Imagery Information Option I to Phase II	18 Aug 97	\$63,007	Not Awarded to CAST
l.	Environmental Protection Agency Gulf of Mexico Program Office Stennis Space Center, MS	PI: R. Passi Equipment Purchases for Virtual Data Warehouse	2 Sep 97	\$28,000	\$28,000
m.	Environmental Protection Agency Gulf of Mexico Program Office Stennis Space Center, MS	PI: R. Passi Software Infrastructure Development of Virtual Data Warehouse	4 Dec 97	\$152,784	\$152,784 FY98/99
n.	Massachusetts Institute of Technology as a Sub- Contractor Under Nat'l Oceanographic Partner- ship Program Cambridge, MA	PI: D.E. Dietrich Littoral Oceanographic and Acoustic Laboratory Support to MIT	19 Jan 98	\$127,845	Not Awarded to CAST

o.	Commander Naval Oceanography and Meteorology Command Under Nat'l Oceanographic Partnership Program, Stennis Space Center, MS	Pis: R. Passi and J. Corbin A Regional Ocean Prediction System and Associated Simulation Exercises	21 Jan 98	\$466,943	Not Awarded to CAST
p.	University of Miami as a Subcontractor under National Oceanographic Partnership Program Miami, FL	PI: D.E. Dietrich Development of a Prototype First-Generation Analysis System for Inter-Americas Seas	17 Feb 98	\$50,000	Not Awarded to CAST
q.	U.S. Geological Survey Federal Geographic Data Committee NSDI Program Reston, VA	PI: R. Passi MSU CAST as a USGS National Geospatial Data Clearing House Node	27 Feb 98	\$40,000	\$40,000 for FY99
r.	Naval Research Laboratory Code 3250, Bldg 1007 Stennis Space Center, MS	PI: J.H. Corbin/V. Anantharaj Development of the Master Environmental Library	27 Apr 95	\$1,369,263 Total Award FY96-98	\$103,722 for FY98
s.	Naval Oceanographic Office (Dr. John Blaha) via the Mississippi Research Consortium and NASA Stennis Space Center, MS	PI: C. Abbott MEL Operation and Maint Services to Support NOPP Gulf of Mexico Ocean Monitoring System	17 Apr 98	\$69,500	\$69,500 for FY99
t.	Naval Oceanographic Office (Dr. Martha Head) via the Mississippi Research Consortium and NASA Stennis Space Center, MS	PI: S. Brahmachari/R. Passi 3D Tides and Wind-Forced Currents for NAVOCEANO	25 May 98	\$49,500	Not Awarded to CAST
u.	Naval Research Laboratory Code 7540: Dr. Ted Tsui Monterey, CA	PI: V. Anantharaj, J. Corbin, J. Chambliss, and M. Zhou Advanced Development MEL FY98-00	5 Jun 98	\$60,000	Add-on Funding Surf Zone FY98/99
v.	Naval Research Laboratory Code 7540: Dr. Ted Tsui Monterey, CA	PI: V. Anantharaj, J. Corbin, J. Chambliss, and M. Zhou Advanced Development MEL FY98-00	5 Jun 98	\$40,000	Add-on Funding Physitron FY98/99
w.	Mississippi EPSCoR Committee Office of Research Mississippi State, MS	PI: D. Dietrich and A. Mehra Design and Implement a Data Assimilating Hindcast/Nowcast/Forecast System for Gulf of Mexico	29 Jul 98	\$333,000	Not Awarded to CAST
x.	Office of Naval Research Attn: ONR 353 DURIP 800 N. Quincy Street Arlington, VA 22217	PI: J. Corbin Request for Computer Equipment to Support CAST Research Program	29 Jul 98	\$157,484	Pending

y.	Naval Oceanographic Office via the Mississippi Research Consortium and NASA Stennis Space Center, MS	PI: C. Abbott Naval Interactive Data Analysis System (NIDAS) Maintenance and Upgrades for FY98/MIW	17 Aug 97	\$114,000	\$114,000 for FY99
z.	Environmental Protection Agency Gulf of Mexico Program Office Stennis Space Center, MS	PI: R. Passi Software Infrastructure Development of Virtual Data Warehouse	20 Aug 98	\$298,000	Pending
aa.	U.S. Geological Survey Contracting Officer 12201 Sunrise Valley Dr Reston, VA 20192	PI: V. Anantharaj Development of Metadata Collection Software in Java Programming Language	3 Sep 98	\$26,058	\$26,058 for FY99
ab.	Naval Research Laboratory Code 7540: Dr. Ted Tsui Monterey, CA	PI: V. Anantharaj, J. Corbin, J. Chambliss, and M. Zhou Advanced Development MEL FY98-00	8 Sep 98	\$33,000	Pending Add-on Funding Dr. Mehra
ac.	Naval Research Laboratory Code 7540: Dr. Ted Tsui Monterey, CA	PI: V. Anantharaj, J. Corbin, J. Chambliss, and M. Zhou Advanced Development MEL FY98-00	8 Sep 98	\$9,182	Pending Add-on Funding A. Qiao

For the MSU Academic Year 1997-98, CAST received \$115,000 in funds from the MSU Vice President for Research to support its costs at Stennis Space Center.

ACKNOWLEDGEMENTS

This research was supported by ONR under Research Grants N00014-95-1-0203, N00014-97-1-0099, and N00014-97-1-0525 with MSU; NRL under Contracts N00014-95-C-6032 and N00173-98-C-6012; NASA Contract NAS13-564 Delivery Orders 131 and 132 with the Naval Oceanographic Office; and Contract MX984100-97-0 with EPA. We greatly appreciate the opportunity afforded to us under these research grants and contracts, and hope that you are pleased with our performance.

We would also like to thank the scientific, technical, and support personnel who were directly funded by CAST through the above research grants and contracts for their superb performance. These individuals included:

FY98 Permanent MSU CAST Personnel

Mr. Clifton Abbott
Mr. Valentine Anantharaj
Mr. Sachin Bhate
Ms. Marie Bock
Mr. Shuvobroto Brahmachari*
Mr. John Chambliss
Mr. James Corbin
Dr. David Dietrich
Mr. Steve Foster
Ms. Yee Lau

Ms. Evelyn Lott
Mr. Alexander Matiyevsky
Dr. Avichal Mehra
Ms. Carolyn Michael
Ms. Stephanie McDaniel
Dr. Ranjit Passi
Mr. Steven Payne
Ms. Midge Wilson
Dr. Lanny Yeske
Mr. Ming Zhou

FY98 Students

Mr. Steven Blum
Mr. Shuvobroto Brahmachari
Ms. Pat Ehrensing
Mr. Sayantan Ganguly
Mr. Brandon Jockman
Mr. Shengyong Li
Mr. Rohit Mehra
Mr. Gabriel Murchison
Mr. Colin Murray
Ms. Alice Qiao
Mr. Min Zhang
Mr. Mike H. Zhou

University of Southern Mississippi
University of Southern Mississippi
University of Southern Mississippi
University of Southern Mississippi
Mississippi State University
University of Southern Mississippi
University of Southern Mississippi
MS Gulf Coast Community College
Florida State University
University of Southern Mississippi
University of Southern Mississippi
University of Southern Mississippi

Consultants

Dr. Zhifan Zhu
Mr. Michael Carpenter

Weather New, Inc., Sunnyvale, CA
Rela, Inc., Boulder, CO

* Former student who accepted full time position in FY98.

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